EEG AND SUBJECTIVE CORRELATES OF ALPHA-FREQUENCY BINAURAL-BEAT STIMULATION COMBINED WITH ALPHA BIOFEEDBACK

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May 1990

This study is dedicated to my Mom and Dad, my sisters, Denise and Diann, and my brother Doug without whose encouragement and support this project would have been much more difficult.

Acknowledgements

I would like to express my appreciation to Dr. Robert Crawford, Dr. Robert Davis, Dr. Todd Davis, Dr. Burl Gilliland and Dr. Kenneth Lichstein for their advice, encouragement and support throughout the completion of this work. I would also like to thank Dr. Jane Davis at Christian Brother's College for the opportunity to solicit participants from her introductory psychology classes. My appreciation also goes out to Dr. Michael Daley, Ryan Eason and Palitha Jayasinghe in the MSU Electrical Engineering Department for their technical assistance in creating the hardware and software necessary for the A/D conversions of the EEG data.

I also express my thanks to Libby Keenan, Coordinator of MSU's Computer Services Training Center, for her help with the software used to transform the raw data. I would also like to thank George Relyea, Manager of MSU's Statistical Services, for his assistance with the SPSSX statistical analysis.

Abstract

The purpose of this study was to determine the effects of alpha-frequency binaural-beat stimulation combined with alpha biofeedback on alpha-frequency brain-wave production and subjective experience of mental and physical relaxation. The study compared the alpha brain-wave production and subjective report of mental and physical relaxation of four groups, each of which received brief relaxation response training and one of four treatments: 1) alpha-frequency binaural-beat stimulation, 2) visual alpha- frequency brain-wave biofeedback, 3) alpha- frequency binaural-beat stimulation combined with visual alpha biofeedback, or 4) artificially produced ocean surf sounds. Sixty volunteer undergraduate and graduate students were randomly assigned to the four groups and instructed to utilize their respective treatment as the "mental device" in Benson's relaxation response paradigm while they relaxed with eyes open for twenty minutes. Two 2 X 4 mixed ANOVAs revealed that all groups evidenced

increased subjective report of relaxation and increased alpha production. An interaction effect was found in which the group with both alpha binaural beats and alpha biofeedback produced more treatment alpha than the group with alpha biofeedback alone. Additionally, nine of the fifteen subjects with both binaural beats and feedback reported being able to control alpha production via their focus on the alpha binaural beats. The data suggest the possibility that binaural beats can be used to evoke specific cortical potentials through a frequency-following response. Further investigation is warranted into the possibilities of using binaural beats alone and in conjunction with brain wave biofeedback to promote the self- regulation and management of consciousness.

Introduction

In recent years, the self-regulation of physiological processes has received an increasing amount of attention from the behavioral science community due to a number of factors, the most important of which is the increasing sophistication of techniques for measuring and feeding back meaningful information concerning these processes. Technological advances in the areas of electronics and computers have promoted the application of cybernetic principles to such biological events as heart rate, blood pressure, skin temperature, electrodermal responses, and spontaneous and evoked cortical potentials (Yates, 1980). The ability to empirically quantify these biological events and their operant control has also sparked renewed interest from behavioral scientists in the objective study of the self- regulation of consciousness (Schwartz & Shapiro, 1976). In fact, although at one time conscious and/or volitional processes were considered to be outside the proper domain of psychological investigation, the study of consciousness is now viewed as a central issue in cognitive psychology (Davidson, Schwartz & Shapiro, 1983).

The empirical investigation of the operant control of spontaneous and evoked cortical potentials began with the invention of the electroencephalograph (EEG) by Richard Caton around 1875 (Empson, 1986). Since that time advances made in EEG technology have enabled feedback of specific cortical potentials in forms which have allowed individuals to achieve control over certain specific cortical potentials under certain conditions (Rockstroh, Birbaumer, Elbert, & Lutzenberber, 1984). EEG technology has promoted the conditioned self-regulation of electrical brain rhythms through biofeedback procedures and thus has enhanced operants' abilities to self-regulate the behaviors and states of consciousness with which those rhythms are associated.

The empirical investigation of the sensory stimulation of cortical potentials also dates from Caton's invention of the EEG. Various forms of rhythmic stimulation such as flashing lights or pulsing sound have been found to entrain the electrical activity of the brain through the

frequency-following response (FFR). Another form of auditory stimulation which may invoke a FFR, although much more subtle than bursts of sound, is binaural beats.

The present study is viewed within the context of the empirical investigation of the self-regulation and management of consciousness. More specifically, the aspects of consciousness which are focused upon are those which relate to the self-regulation and management of alpha-frequency brain waves, a primary correlate of certain aspects of consciousness. A distinction is made between self-regulation and management of consciousness for two reasons. First, much of consciousness appears to be outside the realm of direct self-regulation. For example, regardless of the level of motivation for maintaining a waking state of consciousness, humans find themselves losing consciousness, or falling asleep, almost daily. Second, information concerning past and present events related to consciousness is useful for planning or managing present or future events related to consciousness. For example, if I am aware that I tend to move from a waking state into a sleeping state after being awake for a certain number of hours, then I may use this information to plan to be in or near a bed when that event occurs. Thus those aspects of consciousness which are outside of my direct control are managed rather than regulated.

In relation to this study, two techniques are considered, alpha brain-wave biofeedback and alpha-frequency binaural-beat stimulation. Alpha brain-wave biofeedback is considered a consciousness self-regulation technique while alpha-frequency binaural-beat stimulation is considered a consciousness management technique. The distinction adopted here between self- regulation and management, however, is seen as a conceptual convention for the promotion of clarity. Both techniques could be considered to contain components of both self-regulation and management of consciousness.

Brain wave biofeedback has already been demonstrated to be an effective technique for the self-regulation of consciousness (Brown, 1970; Green & Green, 1979; Kamiya, 1969). Through the presentation of auditory or visual stimuli which convey useful information concerning the amount of alpha or theta brain-wave production, subjects are able to voluntarily increase or decrease the production of those brain waves. Through the self- regulation of a specific cortical rhythm, one begins to control those aspects of consciousness associated with that rhythm. For example, if I am aware that alpha-frequency brain waves are associated with mental relaxation, I may learn to self-regulate my level of mental relaxation by learning to self-regulate my alpha-frequency brain waves. Brain wave biofeedback techniques are presently being used successfully in the operant conditioning of specific frequency bands as well as single neurons (Rockstroh, Birbaumer, Elbert, & Lutzenberger, 1984).

Although the existence of the phenomenon of binaural beats is well documented (Oster, 1973), the application of binaural-beat stimulation as a consciousness management technique has as

yet received little attention except among a small population of researchers (Atwater, 1988; Hutchison, 1986; Monroe, 1982). However the principle of using sensory stimuli to entrain specific cortical rhythms through the frequency- following response is well documented (Gerken, Moushegian, Stillman, & Rupert, 1975; Neher, 1961; Sohmer, Pratt, & Kinarti, 1977; Stillman, Crow, & Moushegian, 1978; Yaguchi, & Iwahara, 1976).

Binaural beats are auditory brainstem responses which originate in the superior olivary nucleus of each hemisphere. They result from the interaction of two different auditory impulses, originating in opposite ears, below 1000 Hz and which differ in frequency between one and 30 Hz (Oster, 1973). For example, if a pure tone of 400 Hz is presented to the right ear and a pure tone of 410 Hz is presented simultaneously to the left ear, an amplitude modulated standing wave of 10 Hz, the difference between the two tones, is experienced as the two wave forms mesh in and out of phase within the superior olivary nuclei. This binaural beat is not heard in the ordinary sense of the word (the human range of hearing is from 20-20,000 Hz). It is perceived as an auditory beat and theoretically can be used to entrain specific neural rhythms through the frequency-following response (FFR)–the tendency for cortical potentials to entrain to or resonate at the frequency of an external stimulus. Thus, it is theoretically possible to utilize a specific binaural-beat frequency as a consciousness management technique to entrain a specific cortical rhythm.

The entrainment of the alpha rhythm is perceived as a justifiable starting point in this investigation. The alpha rhythm was discovered by Hans Berger around 1924 and has been the object of extensive investigation since. However, there is still disagreement concerning the nature and origins of alpha. The alpha frequency range is usually considered to be from eight to twelve cycles per second and is generally associated with a relaxed but awake state of consciousness. Kamiya (1969) was one of the first to demonstrate operant control of the alpha rhythm through an auditory feedback stimulus. Brown (1970) demonstrated operant conditioning of alpha activity through the use of a visual feedback stimulus. Both researchers reported that enhanced alpha activity was usually accompanied by subjective experiences of pleasant affect. Cade and Coxhead (1979), on the basis of EEG data from “some four thousand” (p. vii) subjects, maintain that the maintenance of a prominent alpha rhythm in the EEG is a prerequisite to developing a state of consciousness which they have reportedly quantified and termed “the awakened mind.” Elmer and Alyce Green in their book Beyond Biofeedback report that alpha and theta biofeedback training facilitated states of consciousness which were conducive to creative imagery and personal psychotherapeutic insights.

This study seeks to empirically examine some of the effects of alpha-frequency biofeedback combined with alpha-frequency binaural beats on EEG alpha production and subjective experience of mental and physical arousal. The rationale behind this approach includes the

possibility that learning to enhance alpha-frequency brain waves by allowing the binaural beats to entrain the cortex through a FFR may provide the subject with a skill that is generalizable to other environments.

Purpose

The purpose of this study is to begin to examine some of the electroencephalographic (EEG) and subjective effects of alpha-frequency binaural beats stimulation alone and in combination with alpha-frequency brain-wave biofeedback. Conceivably, as the EEG and subjective effects of binaural beats become better understood, their use as a consciousness management technique will become more effective.

Need for the Study

The literature on alpha biofeedback training illuminates the fact that there is yet much research to be done on the nature of the alpha rhythm and the factors involved in its operant control. The already reported successful practical applications of alpha biofeedback training provide reasonable motivation to continue to explore the phenomenon. Additionally, the preliminary attempts to utilize binaural beats and the FFR to facilitate specific brain-wave frequencies provide adequate justification for further examination of binaural-beat stimulation in order to better understand its effects. A visual eyes-open biofeedback task may serve to compliment the binaural-beat technique by providing the subject a measure of degree of entrainment achieved. A computerized search of the Psychological Abstracts and Index Medicus revealed no examples of research combining alpha biofeedback with a binaural-beat technique. The importance of the alpha rhythm and the possible benefits of its operant control provide motivation to begin to examine alpha biofeedback paradigms in conjunction with binaural beats. This study will examine the effects of both eyes-open visual alpha biofeedback and a binaural-beat technique on the production of alpha-frequency brain waves and subjective report.

RESEARCH QUESTION

This study addresses the broad research question concerning what the individual and interaction effects of alpha-frequency binaural-beat stimulation and alpha biofeedback are upon subjects’ EEG alpha production and subjective experience of mental and physical relaxation.

Hypotheses

The following four hypotheses were tested:

H(1) Alpha frequency binaural-beat stimulation will increase alpha brain wave production above eyes- open baseline levels.

H(2) Visual eyes-open alpha-biofeedback training will increase alpha production above eyes-open baseline levels.

H(3) The combination of visual eyes-open alpha- biofeedback training with alpha-frequency binaural-beat stimulation will interact to increase alpha production more than either technique alone.

H(4) The combination of alpha binaural beats with alpha biofeedback will result in increased subjective report of relaxation.

Definitions of Terms

For the purposes of this research the following terms are operationally defined as follows:

Alpha production: Alpha production is defined as the ratio of the 10.5 Hz band of the Mind Mirror II EEG (Blundell, undated; Cade & Coxhead, 1979) to the entire measured EEG spectrum.

Eyes-open baselines: Eyes-open baselines are defined as the ratio of the 10.5 Hz band of the EEG to the entire measured EEG spectrum during the two minute period of time after orientation and before the procedure while the subject is mentally and physically relaxed in dim ambient light with eyes open and gaze fixed.

Alpha-frequency binaural-beat stimulation: The alpha frequency binaural beats were produced by a model 201B Hemi-Sync Synthesizer (Instruction manual, undated) and vibrated at 10.5 Hz.

Visual eyes-open alpha biofeedback: Alpha feedback was provided by the 10.5 Hz band of a Mind Mirror II EEG (Blundell, undated; Cade & Coxhead, 1979). In dim ambient light subjects observed two lights which indicated strength of alpha production by diverging laterally from a middle point. Orientation to the procedure included information concerning oculomotor strategies which have been found to affect alpha production. Subjects were instructed to maintain a fixed gaze throughout the procedure and not to use other oculomotor strategies to control alpha production.

Subjective report: Subjective report of mental and physical relaxation is defined as scores on a Self-Report Form.

Assumptions

The analysis of variance techniques used in this study rest upon a mathematical model which assumes that the error effects are distributed normally in the treatment population, the error effects are independently determined and distributed in the treatment population, and the error effects vary homogeneously in the treatment population.

Limitations

This study is subject to the following limitations:

Inasmuch as no frequency of binaural beats is provided other than alpha frequency, the assumption is not made that any increase in alpha production is necessarily unique to alpha-frequency binaural-beat stimulation.

Due to the fact that subjects were not screened for susceptibility to the treatment stimuli, the variability of susceptibility between subjects may obscure the findings of treatment effects.

Although subjects were informed of oculomotor strategies which have been found to increase alpha production and instructed uniformly concerning their use, no objective control for use of oculomotor strategies was used.

Although dominant alpha frequencies vary between and among individuals, no effort was made to evaluate and feed back the dominant alpha frequency of subjects. It seems reasonable that a technique which provides a beat frequency which is more natural to the system would have greater impact on the system.

REVIEW OF THE LITERATURE

Since the discovery of the human electroencephalogram (EEG) numerous applications have been found for utilization of the developing knowledge of the electrical rhythms of the brain. Brain wave biofeedback research has contributed evidence of operant control of the EEG and continues to provide increasing illumination into the nature and functions of the brain's electrical rhythms. The interaction of these rhythms with the environment has also become better understood with the aid of EEG technology by allowing measurement of the effects of sensory stimuli on cortical potentials. The frequency-following response (FFR) is the tendency

for the EEG to become entrained to the frequency of an environmental stimulus. The following study employs a combination of alpha brain-wave biofeedback and utilization of the frequency-following response through an alpha-frequency binaural-beat technique in an effort to determine the subjective and EEG correlates of this combination.

Electroencephalography

The history of electroencephalography, the measurement and study of the brain's electrical activity, dates back to the mid- to late nineteenth century when advances made in the science of electromagnetism began to be applied to human physiology. Richard Caton developed a technique for detecting the electrical activity from the exposed surfaces of the brains of living rabbits and monkeys. He demonstrated his findings at a meeting of the British Medical Association in 1875 and later published them in the British Medical Journal (Caton, 1875). He is credited with the discovery of the spontaneous EEG in animals and with demonstrating the ability to detect electrical brain responses to stimuli. In 1924 Hans Berger, a German psychiatrist, developed and applied electroencephalographic techniques for use with humans and in 1929 published his first paper on the subject (Empson, 1986).

Since Berger's discovery, the human EEG has provided information which has promoted a wide variety of discoveries about the brain. Functional roles of different areas of the brain have been discovered (Giannitrapani, 1985), development of the brain has become better understood (Surwillo, 1971), and correlations have been found between EEGs and behavior, personality factors and mental disorders (Saul, David, & Davis, 1949; Glaser, 1963; Robinson, 1974).

The normal human EEG has a frequency range from 0.5 Hertz (Hz) to 30 Hz which is usually subdivided into four or five bands: delta (0.5-3.5 Hz), theta (4-7 Hz), alpha (8-12 Hz), beta (13-28 Hz), and gamma (28+ Hz). Each of these bands has been correlated with specific behavioral states. Delta frequency waves are generally associated with deep sleep, theta waves with light sleep or dreaming, alpha waves with relaxed consciousness, and beta and gamma waves with active consciousness. Modern computerized EEGs can provide immediate feedback of the brain's electrical activity according to location, frequency, and amplitude. This information can be utilized to identify and possibly modify specific functional states of individuals. Also, this information, when compared with normative data, can be used to indicate deficiencies or specialties of function of an individual.

The Alpha Rhythm

Hans Berger is credited with the discovery of the human alpha rhythm in 1924 (Empson, 1986). Berger's first recognizable pattern in the human EEG was a relatively dominant, stable,

synchronous wave form of about ten cycles per second which occurred primarily when the eyes were closed and during states of relaxation. Berger also noted that alpha was replaced by beta waves when the eyes were opened or when the individual was engaged in mental activity such as arithmetic calculations. For Berger, alpha waves represented a form of automatic functioning, a state of electrical readiness which exists when the subject is awake and conscious but inattentive. By 1934 (Adrian & Matthews, 1934) a consensus had been reached that alpha activity was related to relief from both visual activity and attention (Klinger, Greqoire, & Barta, 1973). The relationship of alpha to both the visual/oculomotor system and mental activity has been an important factor in alpha biofeedback research.

In most individuals there is a fairly consistent alpha frequency of around 10 cycles/second (Wieneke, Deinema, Spoelstra, Storm Van Leeuwen, & Versteeg, 1980). Although the alpha range is usually defined to be from 8-12 Hz, within this range the actual dominant alpha frequency varies between individuals (Schwibbe, Bruell, & Becker, 1981), within individuals across time according to differing conditions (Banquet, 1972, 1973), and within some individuals' brains at the same time (Inouye, Shinosaki, Yagasaki, & Shimizu, 1986). This variation of the alpha rhythm within and between individuals illustrates the complex and idiosyncratic nature of the phenomenon. Additionally, numerous variables have been correlated with the alpha rhythm in various ways.

Alpha and Arousal

Some researchers have attempted to relate alpha activity to physiological arousal. The alpha rhythm is most evident when the subject is awake, has closed eyes and is relatively relaxed, and tends to disappear or decrease when the subject engages in mental concentration or physical movement, or becomes tense, apprehensive or anxious. It has thus been described as occupying a mediating position on the continuum of nervous activation ranging from deep sleep to high emotional excitement as described by arousal theory (Malmo, 1959). Lindsley (1952) characterizes synchronized, optimal alpha rhythm as a state of relaxed wakefulness in which attention tends to wander, free association is enhanced, and behavioral efficiency of routine reactions and creative thought is good. Evans (1972) suggests that alpha is related to cognitive arousal and attention in a U-shaped manner in the sense that it disappears at either extreme of arousal and attention. Cade and Coxhead (1979) describe a two factor theory of arousal in which the alpha rhythm is indicative of relaxed cortical arousal. Other physiological measures such as skin resistance reflect peripheral or somatic arousal. In their model cortical and peripheral arousal interact but may vary independently.

Alpha and Hypnosis

A number of researchers have focused on the alpha rhythm as a possible physiological correlate of hypnosis. London, Hart, and Leibovitz (1968) found evidence that hypnotic susceptibility is positively correlated with higher levels of waking alpha production. However, other researchers attempting to replicate this finding have had both positive and negative results (Engstrom, London, & Hart, 1970; Evans, 1972; Galbraith, London, Leibovitz, Cooper, & Hart, 1970; Nowlis & Rhead, 1968; Ulett, Akpinar, & Itil, 1972).

Alpha and Meditation

In the late 1950's and early 1960's research into the EEG effects of meditation began to reveal that the alpha rhythm appears different during meditation and may undergo long-term changes in persistent meditators (Bagchi & Wenger, 1958; Kasamatsu & Hirai, 1969). Anand, Chhina, and Singh (1961) reported that the EEG of meditators showed a high amplitude slowed alpha rhythm which gradually spread from the occipital to the frontal areas. Banquet (1973) also found high amplitude alpha rhythms during meditation. Additionally, Banquet noted a second stage of meditation in which theta frequencies appeared and moved from frontal to posterior channels. A third stage, which Banquet observed in only the most experienced meditators, was characterized by high-frequency beta waves over the whole scalp. Banquet also noted that during meditation alpha blocking did not occur to low intensity light and sound stimulation. Empson (1986) summarizes the recent research on meditation and concludes that the experience of meditation "requires the constant maintenance of a fairly low level of arousal which allows the sort of dissociated, free-associative thinking that meditation entails" (p. 31). The low-frequency, high-amplitude alpha rhythms generally found during meditation thus seem to represent a voluntary lowering of arousal by the meditator.

These findings concerning the EEG activity of meditators sparked increased interest in the meanings of these rhythms and how to control them. Stewart (1974) observes that the interest in alpha brain wave biofeedback training appears to have originated from EEG monitoring of Zen and Yoga practitioners. The perceived link between meditation and alpha production influenced many to assume that increased alpha production would result in the ability to reap the benefits of meditation. This assumption has been a driving force behind the interest in alpha biofeedback training. However, over two decades of research into alpha biofeedback training indicates that this assumption is at best simplistic.

Alpha Biofeedback Training

Alpha biofeedback training was first introduced by Kamiya in 1962 (Kamiya, 1969) when he demonstrated that subjects who were required to guess whether or not alpha was present in their EEGs and were subsequently informed of their accuracy, could, within a few hours, correctly identify when they were producing alpha with high accuracy. He also found that those

subjects who were successful in discrimination training could also produce or suppress alpha activity at will. He later successfully utilized auditory alpha-biofeedback devices which informed subjects of their alpha production through the presentation or absence of a tone generated by their alpha rhythms (Nowlis & Kamiya, 1970). The mental states which Kamiya's subjects associated with increased alpha production were reported to be feelings of relaxation, "letting go," and pleasant affect.

Brown (1970) studied alpha biofeedback in an eyes open condition and found that subjects were able to increase their alpha production with a visual feedback stimulus in the form of a small blue light which was activated by alpha production. She reported that successful alpha enhancement was correlated with subjective experiences of narrowing of awareness and pleasant feeling states. Other researchers have reported successful attempts to enhance alpha production with both visual and auditory feedback (Green, Green, and Walters, 1970; Honorton, Davidson, and Bindler, 1972; Inouye, Sumitsuji, & Matsumoto, 1980). Although Kamiya and Brown used the occipital regions to train alpha, successful alpha training has also occurred using central (Potolicchio, Zukerman, & Chernigovskaya, 1979), parietal and frontal regions (Nowlis & Wortz, 1973). There has also been success training interhemispheric synchronization of alpha (Mikuriya, 1979).

Since the advent of alpha biofeedback training, research in the area has revealed relationships between alpha production and such diverse topics as pain control (Pelletier & Peper, 1977) and extrasensory perception (Rao & Feola, 1979). Alpha production has also been correlated in various ways with creativity (Martindale & Hines, 1975), reaction time (Woodruff, 1975; Ancoli & Green, 1977), locus of control (Goesling, 1974; Johnson & Meyer, 1974), neuroticism (Travis, Kondo, & Knott, 1974b), and other personality variables (Degood & Valle, 1975).

Alpha Training and Contingent Feedback

One of the most fundamental principles of biofeedback is the necessity of accurate monitoring and feedback of the physiological process of interest in order for that process to be operantly controlled. It seems to be a comment on the complexity of the phenomenon of alpha biofeedback that after over twenty years of research there is still a lack of agreement among researchers that the increased alpha production observed in alpha biofeedback training paradigms is dependent upon the presence of accurate contingent feedback. While some researchers contend that alpha control is dependent upon true feedback (Kondo, Travis, Knott, & Bean, 1979; Pressner & Savitsky, 1977; Travis, Kondo, & Knott, 1974a), other researchers have found that alpha enhancement occurs under conditions of false feedback or no feedback and is thus less dependent upon accurate feedback than on other situational factors such as expectancy, instructions, or reinforcements other than the feedback (Brolund & Schallow,

1976; Holmes, Burish, & Frost, 1980; Lindholm & Lowry, 1978; Lynch, Paskewitz, & Orne, 1974; Prewett & Adams, 1976; Williams, 1977).

EEG Alpha and the "Alpha Experience"

According to the early research into alpha control, the successful enhancement of alpha was accompanied by "pleasant feeling states," "dissolving into the environment," altered perception of time, relaxation, "letting go," "letting mind wander," and visual inattentiveness (Brown, 1970; Nowlis & Kamiya, 1970). These observations led to the conclusion that enhanced alpha production resulted in an altered state of consciousness referred to as the "alpha state." However, further research into the subjective experiences which accompany alpha biofeedback training reveal that there are many other factors involved which influence these experiences. While some research indicates that the "alpha experience" requires both enhanced EEG alpha production and an "instructional set" (Walsh, 1974), other research indicates that the "alpha experience" does not necessarily accompany high or enhanced levels of EEG alpha (Plotkin, 1976, 1978; Plotkin & Cohen, 1976; Plotkin, Mazer, & Loewy, 1976), and may be relatively independent of alpha production (Plotkin, 1979). Enhanced alpha has been accompanied by elevated mood states as well as neutral or unpleasant mood changes (Bear, 1977; Cott, Pavloski, & Goldman, 1981; Travis, Kondo, & Knott, 1975). Marshall and Bentler (1976) contend that the level of physical relaxation is probably the determining factor in the experience of the "alpha state" rather than the amount of alpha production. This interpretation lends itself to a discrimination between cognitive and somatic relaxation. Although alpha production is related to both physical and mental arousal, it is neither a necessary consequence of nor a prerequisite to physical relaxation. Nor is it necessarily accompanied by pleasant affect. It is a multifaceted phenomenon which exists in a web of relationships with these and other variables.

Alpha and the Oculomotor System

As was mentioned earlier, Berger recognized that alpha production was somehow associated with both the visual system as well as mental effort. The further definition of these associations has been an ongoing theme since Berger's discovery. While Kamiya and Brown were further defining the links between alpha and subjective experiences of relaxation and pleasant affect, other researchers were further defining the links between alpha and the oculomotor system (Dewan, 1967; Mulholland & Evans, 1966).

The assumption that increased alpha control results in increased control over arousal breaks down when the link between alpha and the oculomotor system is not controlled for (Goodman, 1976). Brown (1974) relates an incident in which a colleague who had been practicing alpha biofeedback requested to have his EEG monitored in her lab to check his progress. They

discovered that he had learned to control his alpha production by moving his eyes, not by producing it by itself. Even though he thought he had learned to control his alpha production by lowering his level of arousal, he had actually only learned to keep the alpha feedback tone on by unconsciously discovering and using another mechanism by which alpha may be controlled. The fact that the alpha rhythm is correlated with numerous cognitive and behavioral variables has spawned controversy over whether or not cognitive strategies are primary factors in alpha control or merely mediate oculomotor control of alpha (Hardt & Kamiya, 1976; Plotkin, 1976a; Plotkin, 1976b).

Alpha Control and Baseline Alpha

The intimate relationship between the oculomotor system and the alpha rhythm has revealed some design difficulties in alpha training procedures. It seems that success in increasing alpha density depends partially on whether or not eyes-open or eyes-closed baselines are used and upon the amount of light available during the training procedure. Paskewitz and Orne (1973) compared two groups of subjects who were trained with alpha feedback tones. One group was trained in total darkness and the other was trained in dim ambient light. The group trained in darkness demonstrated no increases in alpha densities while the group trained in dim ambient light demonstrated increases in alpha densities compared to eyes- open baseline levels. Neither group demonstrated increases in alpha when compared to eyes-closed baselines. They concluded that alpha training can lead to changes in alpha densities only when conditions have lowered alpha densities below the levels spontaneously seen under optimal conditions. They concluded, “Subjects can acquire volitional control over alpha activity only under conditions which normally lead to decreased densities. . . Alpha feedback training may enable a subject to overcome suppressing effects when they are present” (p. 363). They further state that the pleasant subjective experiences reported to be associated with alpha feedback training are likely consequences of the acquisition of skill in disregarding stimuli in the external and internal environments which would ordinarily inhibit alpha activity. Seen within this context, they describe an increase in alpha density as not an end in itself but an index of the subject’s ability to disregard or remain unaffected by alpha blocking stimuli.

Other studies have indicated that the individual subject’s baseline alpha amplitude and density is an important factor in obtaining increases in alpha through feedback training (Kondo, Travis, & Knott, 1973).

Alpha and Attention

Alpha is usually associated with mental states of nonattention, disappearing when the individual focuses attention on something either in the external or internal environments. Brown, however, (1974) reports that during visual alpha feedback training sessions her

subjects demonstrated alpha during the periods when they were attending to the visual stimulus and produced desynchronized beta frequencies during the rest periods when they were not attending to the feedback light. The link between alpha production and attention is thus more complex. She noted that “the subjects who lost awareness of all environmental factors except the light . . . were those subjects with the highest levels of alpha production. Conversely, the subjects who remained aware of the environment . . . produced the smallest amounts of alpha” (Brown, 1974, p. 333). One interpretation of this seeming paradox is that the subjects entered a state of selective attention which did not require an alert, no-alpha EEG. Possibly, the subjects were attending to being nonattentive during the feedback trials and became less attentive to being nonattentive during the rest periods.

Alpha and Anxiety

There are indications that alpha production is related to anxiety (Nowak & Marczynski, 1981). However, the use of alpha-biofeedback training to reduce anxiety has met with mixed success. Hardt and Kamiya (1978) reported that with high trait anxiety subjects alpha training resulted in anxiety reduction in proportion to alpha increases and anxiety increases in proportion to alpha suppression. Watson, Herder, and Passini (1978) report long-term improvement in both state and trait anxiety with alcoholics who participated successfully in alpha training. Plotkin and Rice (1981), however, found that anxiety reduction was related more to perceived success in the feedback task than to actual changes in alpha production. They thus attribute the reductions in anxiety that occur during alpha feedback training to placebo effects.

In a study by Orne and Paskewitz (1974) subjects were given alpha feedback training and were told that their alpha production would determine whether or not they would receive electrical shock during periods signaled by a tone. Although the subjects indicated increased physiological and psychological arousal during times of jeopardy, as measured by increased heart rate, skin conductance responses, and reported subjective apprehension and anxiety, their alpha production was not affected. These results indicate that a reduction in alpha production is not a necessary consequence of increased anxiety or physiological arousal. However, the results do not necessitate the conclusion that increased alpha production does not reduce anxiety.

Therapeutic Applications of Alpha Training

Although there have been reports of unsuccessful attempts to utilize alpha biofeedback training therapeutically (Hord, Lubin, Tracy, Jensma, & Johnson, 1976; Leib, Tryon, & Stroebel, 1976; Mandelzys, Lane, & Marceau, 1981; Watson & Herder, 1980), positive results have been reported with several therapeutic applications. Goldberg, Greenwood, and Taintor (1976) reported that a decrease in illicit drug use accompanied learned control of alpha in four

chemically addicted subjects. Peniston and Kulkosky (1989) utilized alpha-theta brain-wave training with alcoholics and reported long-term improvement in depression scores and sustained prevention of relapse. Alpha training paradigms have been successful in reducing seizures and abnormal brain rhythms in epileptics (Johnson & Meyer, 1974a; Rouse, Peterson, & Shapiro, 1975; Sterman, 1973). Success has been noted in the treatment of migraine headaches (Andreychuk & Skriver, 1975; Cohen, McArthur, & Rickles, 1980), although alpha training was not found to be superior to other biofeedback strategies. The control of pain has been found to be related to alpha production in meditators (Pelletier & Peper, 1977) and alpha-biofeedback strategies have been found to facilitate control of chronic pain in conjunction with hypnotic suggestion (Melzack & Perry, 1975) and stress inoculation training (Hartman & Ainsworth, 1980). Mills and Solyom (1974) used alpha training successfully with five ruminating obsessives and found that virtually no ruminations occurred during alpha, indicating possibilities for further research and application of alpha training in this area. Alpha suppression training has been successful improving performance on an arithmetic task with mentally retarded subjects (Jackson & Eberly, 1982), and improving attention and reading skills (Ludlam, 1981).

Binaural Beats and the Frequency-Following Response

As has already been seen, the alpha rhythm is influenced by many factors, both internal and external. Environmental factors such as photic and auditory stimulation have been found to influence alpha production in various ways. Flickering lights can entrain the electrical rhythms of the brain through the frequency- following response. A more subtle example of the frequency-following response occurs through binaural beats, an auditory brainstem response.

Photic Stimulation

Research clearly indicates the possibility of entraining specific frequencies of brain waves by presenting subjects with frequency-specific flickering lights (Arinibar & Pfurtscheller, 1978; Nogawa, Katayama, Tabata, Ohshio, & Kawahara, 1976; Regan, 1966; Williams & West, 1975; Yaguchi & Iwahara, 1976). For example, alpha-frequency brain waves may be entrained by exposing subjects to a light stimulus flickering at a rate within the alpha frequency range. The tendency for the electrical rhythms of the brain to become entrained to frequencies of sensory stimuli in the environment is called the frequency-following response (Moushegian, Rupert, & Stillman, 1978; Sohmer, Pratt, & Kinarti, 1977; Stillman, Crow, & Moushegian, 1978).

Auditory Stimulation

Research also indicates that auditory stimuli can be used to entrain the electrical rhythms of the brain (Neher, 1961; Picton, Woods, & Proulx, 1978a; Picton, Woods, & Proulx, 1978b). Auditory entrainment of cortical rhythms can occur through two different routes. One may achieve entrainment through bursts of sounds such as through drum beats, or one may achieve entrainment through the less direct and more subtle route of binaural beats.

The range of the electrical rhythms of the human cortex is 0 Hz to about 40 Hz. Since humans have an auditory range of 20 to 20,000 Hz, it is not possible to directly entrain cortical rhythms below 20 Hz with pure tones. However, the phenomenon of binaural beats, an auditory brainstem response, allows the entrainment of frequencies below 30 Hz through the interaction of pure tones within the superior olivary nuclei.

In 1839 H. W. Dove, a German experimenter, discovered the auditory effect of binaural beats (Oster, 1973). He found that when two different frequencies of sound were presented, one to each ear, a third frequency equal to the difference between the two frequencies was experienced. This third, binaural beat is actually the result of the interaction of the two primary tones within the auditory brainstem. For example, if a pure tone with a frequency of 400 Hz is presented to one ear and a second tone of 410 Hz is presented to the other ear, a third binaural beat with a frequency of 10 Hz will also be heard as a result of the interaction of the two frequencies. Binaural beats can be generated at frequencies below 40 Hz and may be used to entrain electrical rhythms of the brain to vibrate at the same frequency through the frequency-following response (Dobie & Norton, 1980; Gerken, Moushegian, Stillman, & Rupert, 1975; Moushegian, Rupert, & Stillman, 1978; Smith, Marsh, & Brown, 1975; Smith, Marsh, Greenberg, & Brown, 1978; Sohmer, Pratt, & Kinarti, 1977; Stillman, Crow, & Moushegian, 1978; Yamada, Yamane, & Kodera, 1977). Mediating processes through which the auditory brainstem binaural beat may entrain the cortex are likely to include attentional and motivational factors. Binaural-beat techniques are reportedly being used to successfully entrain specific brain-wave frequencies for specific purposes (Atwater, 1988). Preliminary reports indicate that the techniques may lend themselves to therapeutic applications. The combination of binaural beats and brain wave biofeedback may also prove therapeutically useful in the future.

METHODOLOGY

The Pilot Study

A pilot study was implemented January 1989, in order to further define the parameters necessary to test the utility of binaural beats in enhancing alpha production. The purposes of the study were to determine (a) the effectiveness of the binaural- beat technique in enhancing alpha production within a single session, (b) the effectiveness of the binaural-beat technique in

enhancing alpha production across sessions, and (c) the number of sessions necessary in order for the binaural-beat technique to enhance the self-regulation of alpha in subjects.

Method

Subjects

Four volunteer students, one undergraduate female, one graduate female, one undergraduate male, and one graduate male, were used ranging in age from 20-38. A total of eighteen sessions of usable data was compiled. One subject completed six sessions, two subjects completed five sessions, and one subject completed two sessions.

Procedure

The initial session included a discussion of a handout describing the components of the “relaxation response” (Benson, 1975) and a brief introduction to the binaural-beat phenomenon. Subjects were told that the experiment was designed to provide a binaural beat to serve as the “mental device” (p. 27) in Benson’s paradigm. Subjects were reminded of the importance of maintaining a passive attitude and focusing on the binaural beat before each session.

The procedure for each session was the same; (a) subjects completed a brief pre-test of subjective experience of relaxation and anxiety, (b) subjects were given instructions to relax and breathe slowly and deeply for three to five minutes, (c) EEG activity was recorded while subjects listened with eyes closed for seven minutes each to three conditions of sound– artificially produced surf sounds, surf sounds with audible alpha-frequency binaural beats, and surf sounds with subaudible alpha-frequency binaural beats, (d) subjects completed a brief post-test of subjective experience of the procedure and levels of relaxation and anxiety.

Instruments

The binaural beats were produced by a Model 201B Hemi-Sync Synthesizer (“Instruction Manual,” undated). EEGs were recorded bipolarly from occipital and temporal sites of both hemispheres (T3, T4, 01, & 02 sites as per Jasper, 1958) by a Mind Mirror II EEG (Blundell, undated; Cade & Coxhead, 1979).

Scoring

Average alpha ratios were computed for each condition of each session. Each of the 28 channels was sampled three times per second. For each condition a ratio of alpha/all frequencies was computed. These ratios were utilized in the statistical analysis.

Results

Early in the study it became evident that methodological refinements were needed in order to demonstrate any effects of the binaural beats. The analysis of variance of the data revealed that there were no significant differences in alpha production either within sessions across conditions or across sessions. Although alpha production was observed to increase in the binaural-beats condition early in some sessions, a tendency was observed for the subjects to move through alpha into desynchronized theta, indicating light sleep. Subjective reports of “dozing off” corroborated these observations. These periods of light sleep, almost devoid of alpha, affected the average alpha ratios.

Subjective reports indicated that the procedure was experienced as either pleasing and relaxing or neutral. Open interviews revealed that one subject who was certain he had found the key and was controlling his alpha was in actuality producing no more EEG alpha than before.

DISCUSSION

Since the procedural conditions of the pilot study were insufficient to document that the alpha binaural beats could stimulate increased alpha, the strategy of adding the biofeedback task was conceived to provide subjects with an ongoing measure of success. It is conceivable that with feedback, subjects will be able to discover successful strategies for letting the binaural beats entrain their brain rhythms to the frequency of the stimulus.

The Study

Based on the results reported in the pilot study, the following study was conducted which incorporates a feedback condition into the binaural-beat procedure. The feedback will theoretically provide the subject a measure of the success with which he or she is allowing the binaural beat to entrain the EEG.

Subjects

Sixty volunteer undergraduate and graduate students from Memphis State University and Christian Brother’s College participated in the study. The students from Christian Brother’s

College were volunteers from Jane Davis' introductory psychology classes. The Memphis State students were from Burl Gilliland's, Bob Davis', and Fleetis Hannah's counseling classes. Participants were screened for known neurological damage and abnormalities.

Instrumentation

The binaural beats were provided by a model 201B Hemi-Sync Synthesizer ("Instruction Manual," undated). The alpha-frequency binaural beats were created by presenting two pure tones, one to each ear, through a set of headphones, which differed in frequency by 10.5 Hz. The instrument was tested for validity and reliability on an oscilloscope and found to meet adequate standards for both.

EEGs were recorded bipolarly from occipital and temporal sites of both hemispheres (T3, T4, 01, 02 sites as per Jasper, 1958) by a Mind Mirror II EEG (Blundell, undated; Cade & Coxhead, 1979). After recording the EEGs on magnetic tape, the information was converted to digital form and computer analyzed.

Design and Procedure

Sixty subjects received brief relaxation response training based on a handout they were given, and randomly assigned to one of four groups: (a) alpha frequency binaural-beat stimulation, (b) visual, eyes-open alpha brain-wave biofeedback, (c) both alpha-frequency binaural beats and alpha biofeedback, or (d) artificially produced surf sounds. The ratio of males to females was kept constant for all groups.

The procedure for each subject consisted of the following steps: (a) the subject completed a pre- test of subjective mental and physical relaxation, (b) the subject was introduced to the four components of the "relaxation response" (Benson, 1975), (c) the subject was introduced to the stimulus which served as the mental device to theoretically elicit the relaxation response (either alpha binaural beats, alpha biofeedback, both, or phased white noise), (d) the subject was connected to the EEG, (e) the subject was instructed to become comfortable, relax, and breathe slowly and deeply for three to four minutes, (f) a two-minute eyes-open EEG baseline was recorded, (g) the subject was provided with the appropriate stimulus and allowed to become oriented to the situation, (h) the subject engaged in a ten minute eyes-open session of attempting to passively allow the stimulus to serve as the mental device to elicit the relaxation response, (i) the subject was briefly interviewed concerning strategies being used and subjective experience of the procedure and possibly reminded of previously mentioned strategies, (j) the subject engaged in a second ten minute session identical to the first, (k) the subject was disconnected from the EEG, (l) the subject completed the Self-Report Form and was interviewed concerning subjective experience of the procedure.

Data Analysis

Hypotheses H(1), H(2), and H(3) were tested by utilizing a 2 X 4 mixed analysis of variance and appropriate follow-up procedures. The between subjects independent variable was be the specific stimulus used by the subject as a mental device to elicit the relaxation response. The within- subjects variable was the time of the sampling of the alpha production; baseline or treatment sample. The dependent variable was the alpha production of the subject.

Hypothesis H(4) was tested by utilizing a 2 X 4 mixed analysis of variance with appropriate follow- up procedures. The between subjects independent variable was the stimulus used as the mental device and the within subjects independent variable was the time of testing; pre- or post- procedure. The dependent variable was the level of relaxation reported.

Summary

This study attempts to examine the effects of alpha-frequency binaural-beat stimulation combined with alpha-frequency brain-wave biofeedback on alpha production and subjective report of relaxation through the utilization of a 2 X 4 mixed ANOVA design. It seems plausible that the combination of visual alpha feedback and alpha binaural beats will enhance the frequency- following response and assist the subjects voluntarily entrain their cortical rhythms to the stimulus.

Analysis of the Data Demographics of Subject Sample

Sixty volunteer subjects, forty females and twenty males, from various Memphis State counseling classes and from two Christian Brother’s College introductory psychology classes participated in the study. Volunteers from Christian Brother’s College were offered extra credit for their participation. Subjects were solicited by the author to participate in a study of the relaxation response. Age of subjects ranged from eighteen to forty-five with a mean of 27.7, a mode of 19, and a standard deviation of 7.64. Data was gathered between October 6, 1989 and October 21, 1989.

Data Analysis Techniques

Subjects were randomly assigned to four treatment groups of fifteen, each with ten females and five males. Each of the four groups received brief relaxation training followed by one of four treatments, a) alpha-frequency binaural-beat stimulation, b) alpha-frequency brain-wave feedback, c) alpha-frequency binaural beats with alpha-frequency brain-wave feedback, or d) artificially produced ocean surf sounds. Baseline and treatment alpha production ratios were

obtained as well as pre- and posttreatment measures of subjective experience of mental and physical relaxation. The data was analyzed using the Statistical Package for the Social Sciences X (SPSSX) analysis of variance and follow-up procedures (Norusis, 1988). Since the form of the alpha production scores was proportional, arcsine transformations were performed on the alpha ratios prior to analysis in order to promote homogeneity of error variance and normality of error effects and to obtain additivity of effects (Kirk, 1982). For the experimental effects which achieved significance, the omega squared statistic was computed to indicate the strength of the associations (Kirk, 1982).

Assumptions

The mathematical model upon which the SPSSX analysis of variance procedures rest assumes that the error effects are distributed normally in the treatment population, independently determined and distributed in the treatment population, and vary homogeneously in the treatment population. The degree to which these assumptions were met affects the validity of the findings.

Homogeneity of variance.

Homogeneity of variance is a major assumption underlying the SPSSX analysis of variance procedures. The Bartlett-Box F test for univariate homogeneity of variance was used as a starting point for testing this assumption. The results of this procedure are reported in Table 1.

Table 1

Bartlett-Box F Test for Homogeneity of Variance

Measure	F	P
Alpha Production		
Baseline	1.109	.344
Treatment	2.305	.075
Relaxation Scores		
Pre-test	0.121	.948
Post-test	0.735	.531

The significance levels indicate that there is no reason to reject the hypothesis that the variances in the two groups are equal. However, an additional test which examines the variances and covariances simultaneously is necessary in order to sufficiently test for homogeneity of dispersion (Norusis, 1988).

Homogeneity of dispersion.

Homogeneity of dispersion matrices must be considered when using multivariate analysis of variance (Norusis, 1988). Box's M test is based on the determinants of the variance-covariance matrices in each cell as well as the pooled variance-covariance matrices, thus providing a multivariate test for the homogeneity of the matrices. The results of this procedure are presented in Table 2. As indicated, there appears to be no reason to reject the hypothesis that the variance-covariance matrices are equal across all levels of the between-subjects factors. We can conclude, therefore, that the assumption of homogeneity of variance of the error effects is not violated in this data set.

Table 2

Box's M Test for Homogeneity of Dispersion

Measure	F	P
Alpha Production	1.128	.338
Total Relaxation	0.317	.970

Hypothesis 1

It was hypothesized that alpha-frequency binaural- beat-stimulation would increase alpha brain wave production above eyes-open baseline levels.

Table 3 shows the results of the 2 X 4 SPSSX repeated measures ANOVA of alpha production.

Table 3

ANOVA Summary for Alpha Production Ratios

Source	SS	df	MS	F
Between	.01	3	.003	1.07
Error	.20	56	.004	
Within	.04	1	.04	101.84*
Interaction	.01	3	.003	4.16**
Error	.02	56	.0004	

*p < .01
**p < .05

Between effect showed no significant differences among the groups, indicating that all groups were essentially equal in their baseline alpha production. However, the within effect, the difference between baseline and treatment alpha ratios, was significant ($F(1,56) = 101.84$; $p<.01$). Table 4 displays the group means for baseline and treatment alpha production.

Table 4

Mean Alpha Production Ratios

Group	Baseline Mean SD	Treatment Mean SD	Marginal* Mean
A	.081 (.033)	.114 (.044)	.098
B	.073 (.028)	.092 (.033)	.083
C	.084 (.040)	.134 (.052)	.109
D	.075 (.045)	.127 (.068)	.101
*	.078 (.036)	.117 (.052)	.098

*row and/or column averages

Additionally, a significant interaction effect was found ($F(3,56) = 4.16$; $p<.05$), indicating that significant differences were present in cell group means.

Post-hoc analysis was accomplished by the SPSSX one-way analysis of variance follow-up procedure. As demonstrated by Table 5, the treatment alpha production ratio of Group A was found to be significantly higher than the baseline alpha production ratio ($F(1,56) = 93.34$; $p<.01$). Thus Hypothesis 1 was not rejected. Omega squared for the effect (= .613) indicates that we can conclude that the treatment for group A accounts for about 61% of the variance in the alpha production scores.

Table 5

ANOVA Summary for Followup on Group A

Source	SS	df	MS	F
Between groups	.0327	1	.0327	93.3429*
Error	.0196	56	.0004	

*p < .01

Hypothesis 2

It was hypothesized that visual eyes-open alpha biofeedback training will increase alpha production above eyes-open baseline levels.

As demonstrated by Table 6, post-hoc analysis reveals that the treatment alpha production ratio of Group B was found to be significantly higher than the baseline alpha production ratio of Group B (F(1,56) = 30.94; p<.01). Thus Hypothesis 2 was not rejected. Omega squared (= .346) indicates that the treatment accounts for about 35% of the variance in the alpha production scores of Group B.

Table 6

ANOVA Summary for Followup on Group B

Source	SS	df	MS	F
Between Groups	.0108	1	.0108	30.9429*
Error	.0196	56	.0004	

*p < .01

Hypothesis 3

It was hypothesized that the combination of visual eyes-open alpha biofeedback training with alpha frequency binaural beats stimulation will interact to increase alpha production more than either technique alone.

As demonstrated by Table 7, post-hoc analysis reveals that the treatment alpha production ratio of Group C is significantly higher than the baseline alpha production ratio (F(1,56) = 214.29; p < .01). Omega squared (= .785) indicates that the treatment effects account for about 79% of the variance in the alpha production of Group C.

Table 7

ANOVA Summary for Followup on Group C

Source	SS	df	MS	F

Between Groups .0750 1 .0750 214.286*
Error .0196 56 .0004

*p < .01
Follow-up analysis of the interactions between groups is displayed in Table 8. As indicated, a significant interaction was found ($F(3,112)=2.6914$; $p < .05$).

Table 8

ANOVA Summary for Followup on Interaction

Source SS df MS F
Between Groups .0153 3 .0051 2.6914*
Error .2128 112 .0019
*p < .05

Tukey's HSD test revealed that the groups which were significantly different at the .05 level were Groups B and C. Omega squared (= .0417) indicates that the differential treatment of groups B and C accounts for about 4% of the variance between the two groups' alpha production scores.

Group C did not differ significantly from Group A, thus Hypothesis 3 was rejected.

Hypothesis 4

It was hypothesized the combination of alpha binaural beats with alpha biofeedback would result in increased subjective report of relaxation.

Table 9 displays the results of the 2 X 4 SPSSX repeated measures ANOVA on subjective report of

Table 9

ANOVA Summary for Subjective Report of Total Relaxation

Source SS df MS F
Between 37.67 3 12.56 1.20
Error 585.20 56 10.45
Within 1116.30 1 1116.30 214.97*
Interaction 19.90 3 6.63 1.28

Error 290.80 56 5.19
*p < .01

Between effect showed no significant difference among the groups, indicating that the groups were essentially equal in their pretest scores on subjective report of mental and physical relaxation. However, results also indicated that the within effect, the difference between pre- and post-test scores of mental and physical relaxation, was significant ($F(1,56) = 214.97$; $p<.01$). No interaction effect was found. Table 10 provides the means and standard deviations of the pre- and post-treatment scores of relaxations.

Table 10

ANOVA Summary for Mean Subjective Report of Total Relaxation

	Pre-test	Post-test	Margin*
Group	Mean SD	Mean SD	Mean
A	11.1 (3.62)	4.07 (1.67)	7.59
B	10.2 (3.26)	4.53 (2.33)	7.37
C	11.3 (3.56)	6.33 (1.76)	8.82
D	11.4 (3.16)	4.73 (2.22)	8.07
	11.0 (3.40)	4.92 (2.00)	7.96

*row and/or column averages

In relation to Hypothesis 4, the post-treatment relaxation scores of Group C were found to be significantly higher than the pre-treatment scores ($F(1,56)=144.51$; $p<.01$), resultantly Hypothesis 4 was not rejected. Table 11 displays the results of the follow-up ANOVA on pre- and post-test total relaxation scores. Omega squared (= .712) indicates that the treatment effects account for about 71% of the variance in the total relaxation scores of Group C.

Table 11

ANOVA Summary for Follow-up on Group C Total Relaxation

Source	SS	df	MS	F
Between Groups	750.0	1	750.0	144.5*
Error	290.6	56	5.19	

*p < .01

Qualitative Data Gathered

In addition to the quantitative data gathered, anecdotal information was gathered during open interviews which supplements the quantitative data already reported. At the end of the procedure, each subject was uniformly asked, “How was your experience?” Subjects in groups A and C were also asked, “How was your experience of the beats?” Subjects in groups B and C were asked, “How was your experience of the feedback?” and “What strategies were successful in increasing alpha?” Subjects in group C were asked, “Were there any associations between your focus on the beats and your alpha production?” Group D subjects were asked, “How was your experience of the surf sounds?” Information concerning the responses to these questions is reported as it relates to common themes among the groups and differential themes between the groups.

All Groups

The characteristic response of subjects, regardless of the treatment group, was that the experience was enjoyable, pleasant and relaxing. Numerous subjects reported various visual, auditory, tactile or kinesthetic sensations. These sensations are reported in relation to the group or treatment with which they were associated. A number of subjects in all groups reported drowsiness and a desire to close the eyes. Other common themes reported were feelings of peace, calm and tranquility, altered perception of time, feelings of numbness, and disassociation from the body. An additional theme noted in all groups was difficulty eliminating intrusive thoughts.

Associations With the Binaural Beats

Subjects in groups A and C received alpha- frequency binaural-beat stimulation. In response to the question, “How was your experience of the beats?” the following themes were noted: a) the beats were comfortable, pleasant and relaxing, b) felt more physically relaxed when focused on the beats, c) the beat was helpful in eliminating intrusive thoughts and relaxing mentally, d) perception of the beat tended to change in frequency and amplitude, depending on focus e) creative imagery or insights came to mind, f) physical sensations such as bodily warmth or tingling, and g) intracranial sensations, such as feelings of light pressure, especially in the temporal and frontal areas.

Three subjects reported difficulty focusing on the beat. Three subjects with previous meditation experience reported the beats to be more relaxing than other relaxation or meditation strategies. One subject reported that she could use the memory of the beat to recall the feelings she experienced with it.

One subject reported that the color of the visual stimulus seemed to fade when focusing on the tones. The same subject noted a visual perception of a clockwise rotation of the colors green and red at a rate of about two cycles per second.

Two subjects associated the beats with sensations in the sinuses; one reported that the beat caused a pressure build-up while another reported that the beat seemed to cause her sinus drainage to stop. The subject who reported that the beats caused her sinus drainage to stop reported that she “moved it around my body and it stopped my cough and relieved the tension in my neck.”

Associations With Alpha Feedback

Subjects in groups B and C received alpha feedback and were asked how they experienced the feedback and what strategies were helpful in increasing alpha. Subjects generally reported that the feedback was pleasant and interesting. Several also reported that it was difficult not to let the movement of the lights interfere with their efforts to become mentally relaxed.

Themes which surfaced in regard to successful strategies discovered included a) confirmation of oculomotor strategies which affected alpha, b) deep breathing and or exhalation was associated with increased alpha, c) verbal strategies such as affirmations increased alpha, d) mental imagery such as pleasant memories or scenes increased alpha, e) mental effort or thinking decreased alpha, f) alpha increased when momentarily between thoughts, g) alpha increased when focused on the binaural beats, and h) it became easier to control alpha production as the session progressed.

Three subjects reported identifying no successful strategies for increasing alpha and two reported identifying no feelings which corresponded to increased alpha.

Associations With the Surf Sounds

In response to questions regarding experience of the surf sounds subjects unanimously reported positive feelings and associations. There seemed to be a higher level of enthusiasm for the surf sounds than for the binaural beats. One obvious explanation is that surf sounds often are associated with pleasant beach and ocean memories. Several subjects in Group D reported such associations.

Group C

Group C subjects were asked uniformly if they noticed any correlation between their focus on the binaural beat and the movement of the two lights indicating increased alpha. Nine of the

fifteen subjects stated in various ways that focusing on the beat was a successful strategy in increasing alpha. The following statements are verbatim reports from four of these subjects:

Subject #53 was observed to have an unusually high alpha production near the end of the session. During the interview he reported to have gained complete control of the lights by his focus on the beats. He stated, “The beat increased slightly in frequency and volume right after alpha increased dramatically. Then I used that memory to make alpha increase again.”

Subject #56 reported that he felt “a moving rolling pressure across the frontal area and then filling both sides as the beats filled my mind and the alpha increased.”

Subject #27 reported “the tones became like a bar in the front of my head and when the bar formed the beat disappeared and the alpha increased.”

Subject #34 reported that she “was able to focus on the lower tone in my right ear and bring it to the other until when they came together and I heard the beat, the alpha lights would go all the way out.”

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS SUMMARY

The data provides evidence that all groups demonstrated increases in alpha production and subjective experience of both mental and physical relaxation resulting from the treatment procedures. The only interaction found was that of groups B and C. Under the conditions of this study, the combination of alpha-frequency binaural beats and alpha brain-wave feedback resulted in significantly more alpha production than alpha brain-wave feedback alone.

Conclusions

The conclusions that can be drawn from this study are presented as they relate to each hypothesis.

Hypothesis 1

Hypothesis 1, that alpha-frequency binaural beats stimulation would increase alpha brain wave production, was not rejected. However, the increase in alpha production over baseline was due to numerous factors, one of which was the binaural- beat stimulation. The subjects also received brief relaxation response instructions and conditions conducive to relaxation were provided. It should be noted that group A, which received alpha- frequency binaural beats, did not differ significantly in treatment alpha production from Group D, which received artificially

produced surf sounds. It cannot be concluded from this data that the increase in alpha for Group A was due to a frequency-following response.

Hypothesis 2

Hypothesis 2, that visual eyes-open alpha- frequency biofeedback training would increase alpha production above eyes-open baseline levels, was not rejected. However, the amount of alpha increase which is due to the biofeedback training as opposed to other treatment effects such as the relaxation-response training or naturally occurring biological rhythms is indeterminable from these results.

Hypothesis 3

Hypothesis 3, that the combination of alpha feedback and alpha binaural beats would interact to increase alpha production more than either technique alone, was rejected. The treatment alpha production of Group C (feedback and beats) was significantly greater than that of Group B (feedback only) but not that of Group A (beats only). Before concluding that the difference between Groups B and C was due to the alpha- frequency binaural beats, it must be noted that the most parsimonious explanation of this difference is that the addition of a pleasant, constant auditory stimulus made conditions more conducive to spontaneous alpha for subjects in Group C. These results do not necessarily lead to the conclusion that the increase in alpha-frequency brain-wave production is due specifically to the presentation of alpha-frequency binaural beats. It should be noted that Group C did not differ significantly in alpha production from Group D, which also received a pleasant, constant auditory stimulus.

A conceptual distinction between spontaneous and evoked cortical potentials is helpful when considering the effects of alpha-frequency binaural beats. Since the human alpha rhythm is a naturally occurring or spontaneous rhythm of the cortex, deciding how much if any of the alpha production was evoked by the alpha-frequency binaural beats is difficult. Due to methodological limitations of this study, it is impossible to state conclusively that any of the alpha production was evoked. It could be argue that the most parsimonious explanation of the difference in alpha production between groups B and C is that group C conditions were more optimal for spontaneous alpha due to the addition of a constant, pleasant auditory stimulus.

It is useful to note that subjects in groups B and C were presented with conditions which usually induce alpha blocking. The alpha feedback was both visual and moving, and subjects were given the tasks of identifying associations with increased alpha and strategies which caused alpha to increase. Given this information–the visual stimuli and complex tasks of these groups–it might be expected that these two groups would produce less treatment alpha than the other seemingly less active groups. Since these two groups produced as much treatment

alpha as the other two groups, it could then be argued that these two groups were resultantly more active in their production of alpha than the other two groups. The additional information in the next section concerning the subjective reports of associations made between the beats and alpha production may promote the argument that a significant part of that activity involved, for group C, an active focus on the binaural beats.

ASSOCIATIONS BETWEEN ALPHA BEATS AND ALPHA PRODUCTION

The subjective reports of associations between alpha production and focus on the alpha frequency beats are not only worthy of note but perhaps the most significant findings of this study. Nine of the fifteen subjects in Group C reported that increased attention to the beats was associated with increased alpha production. One might argue that since this association was implied by the conditions of the treatment, subjects were simply responding to suggestion or expectation effects. However, the detail of the events involved in the association reported by several of the subjects warrants a consideration of the possibility that these subjects did in fact voluntarily self- regulate their own alpha production by their attentional focus on the beats. Another possibility that warrants consideration is that a portion of the alpha production of these subjects was evoked by the alpha frequency binaural beats.

Hypothesis 4

Hypothesis 4, that the combination of alpha binaural beats with alpha biofeedback would result in increased subjective report of relaxation, was not rejected. Evidently the procedure was experienced to be both mentally and physically relaxing. Since there was no interaction among the groups, the beats and feedback procedure was found to be no more relaxing than the other procedures.

Recommendations

The following recommendations are made in regard to the further investigation of the interactions of binaural beats and biofeedback for the purpose of facilitating self-regulation and management of consciousness:

The use of additional beat frequencies and feedback techniques and such methodological refinements necessary to enable more conclusive statements concerning the ability of binaural beats to entrain electrocortical rhythms.

Longitudinal quantification of the effects of binaural-beat techniques on states of consciousness.

The integration of EEG measurement, assessment and feedback wherein naturally occurring rhythms are detected and appropriate binaural beats are fed back which stabilize or enhance a desired indigenous state of consciousness or entrain an otherwise targeted state of consciousness.

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Self-Report Form

Name: Date: Time:

Sex: F M Age: Group: A B C D

Level of Relaxation (pre-procedure):

Mental.

relaxed 1 2 3 4 5 6 7 8 9 10 tense

Physical.

relaxed 1 2 3 4 5 6 7 8 9 10 tense

Level of Relaxation (post-procedure):

Mental.

relaxed 1 2 3 4 5 6 7 8 9 10 tense

Physical.

relaxed 1 2 3 4 5 6 7 8 9 10 tense

Comments

Relaxation Response Handout

The relaxation response is an integrated mind/body reaction which has been found to have such benefits as increased mental and physical health and improved ability to deal with tension and stress. Some physiological components of the response are decreased oxygen consumption, decreased respiratiry rate, decreased heart rate, and increased alpha brain wave production. An individual’s ability to voluntarily control the relaxation response thus enables a degree of control over these bodily processes. Also, gaining voluntary control of these physical processes results in greater control of the general relaxation response.

Herbert Benson in his book The Relaxation Response (1975), surveys some of the major techniques used for eliciting the relaxation response and describes the essential components of these techniques:

A Mental Device. A constant stimulus such as a sound, word, or phrase repeated silently or audibly, or fixed gazing at an object.

A Passive Attitude. If distracting thoughts occur they should be disregarded and one’s attention should be redirected to the technique. One should not worry about how well he or she is doing.

A Relaxed Body. A comfortable position free from muscular stress.

A Quiet Environment. A location free from distracting stimuli.

The research indicates that those individuals who have gained a degree of control over their relaxation response and the accompanying physiological processes through this technique have done so through regular practice. Just like any skill, practice tends to improve performance. Benson recommends that one practice the technique for ten to twenty minutes once or twice per day.

An important component of the ability to voluntarily control the relaxation response is an identification of the subjective feelings associated with it. Once one knows where a place is, getting there becomes easier.

Thanks for volunteering to participate in this study of the relaxation response. I hope you enjoy it as much as I do.